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THE LIFE WORK OF A SCIENTIFIC ENGINEER.

Original Papers by the late John Hopkinson, D.Sc., F.R.S. Vol i., Technical Papers. Edited by B. Hopkinson. Pp. lxvi+294. Vol. ii., Scientific Papers. Pp. vii+393. (Cambridge: University Press; London: C. J. Clay and Sons, 1901.) Price 10*s*. 6*d*. net each volume.

THREE years have elapsed since the two volumes of original papers by the late Dr. Hopkinson were published, and an explanation is naturally required for such a protracted interval being allowed to elapse before the work was reviewed in these pages. Shortly after its appearance, the writer became seriously ill, and the diminished vigour that accompanied a long tedious convalescence was marked by increased requests that work should be undertaken, exemplifying apparently the anecdote of the doctor who to obtain rest doubled his fees, but only succeeded thereby in doubling his practice. Hence the performance of a duty had to be postponed again and again, and it was not until Mr. C. S. Whitehead was kind enough to bring his mathematical power to bear on a critical analysis of this collection of papers and furnish the substance of much which follows that this tardy review came to be written.

In these two volumes we have the collected works of a man eminent not merely as a scientific investigator, but also as an engineer; they constitute the record of a worker who took a very leading part in showing his fellow electrical engineers how the application of scientific theory and knowledge helped more than crude trial and error in solving some of the numerous problems with which their industry abounds. Pioneers, as a rule, have the mortification of seeing their advances overlooked and neglected by their contemporaries, but Dr. Hopkinson had the happy fortune of being spared this; indeed, his papers resemble the writings of Shakespeare in that they appear to be full of quotations.

It might have been expected that a mathematician like Hopkinson a senior wrangler and Smith's prizeman, would have freely used mathematical processes of some complexity, a transformer, for example, offering a most tempting field for mathematical excursion. But this is far from being the case; the great majority of the processes are such as can be easily understood by anyone moderately well versed in the calculus. But it must not be supposed that all these papers are easy reading; some of them are far from it, and it often takes considerable thought to grasp their meaning.

The first volume contains the technical portion of the papers, and opens with two dealing with lighthouses, one pointing out the advantages of what are known as group-flashing lights, the other describing the optical and electrical apparatus at the lighthouses of Macquarie and Tino.

The remainder of the volume deals almost exclusively with dynamo electric machinery. In the papers reprinted therein Dr. Hopkinson first shows how the curves now universally known as the "characteristic curves" are to be plotted, and then how to extract useful information from them; how, for instance, to determine the lowest speed at which a given dynamo can produce a short arc. He then directs attention to the necessity of taking account of both colour and direction in measurements of the brightness of the electric arc. A little further on we come to two papers on dynamo electric machinery, the first of which was written in conjunction with his brother, Dr. E. Hopkinson, in 1886. In these papers, which were published at about the same time as an equally important one on the same subject by Mr. Kapp, we are shown how the characteristic may be predetermined from theoretical principles based on the equations of a magnetic circuit, and on the magnetic properties of iron as found by experiment.

The paper of 1886 is classical, for with that of Mr. Kapp it laid the foundation of the design of electric machinery. Previously the proper shape to give to a dynamo was unknown, and it was impossible to foresee what effect on the performance of a dynamo would result from altering its shape. The late Prof. Rowland advocated long, lanky-legged machines, and Mr. Edison told the writer that the most astonishing thing in his life was finding that the dynamo which he sent to the Paris Electrical Exhibition of 1881 developed about the amount of electric power that he had hoped it might give.

Next follows the ingenious and economical method of testing the efficiency of a dynamo by coupling it mechanically to another of approximately equal size, and measuring the extra power that had to be supplied from an external source to keep the combination running when one of the machines acted as a motor and drove the second, which in its turn acted as a dynamo and supplied current to the first.

In reading through these papers one cannot fail to be struck with the keen insight which their author displays in picking out the essential points needing examination in the machine under discussion, and with the beautiful methods which he employs for presenting the results of his investigations. Thus, in his papers on the dynamo, he realised that, if the machine were to be improved by scientific study, it was absolutely necessary to ascertain, not merely how much power was put into it, and how much came out in a useful electrical form, but also what was going on in the various parts of the machine itself. Others before him had considered the input and output. Dr. Hopkinson, in conjunction with his brother, took up the second, and equally important, part of this investigation, and gave the results to the world in a manner that was as simple in expression as it was novel in conception.

The papers on alternating currents are, speaking generally, more important for what they suggest than for what they actually prove. Thus, to take those that deal with the parallel running of alternators. Two lines of argument in support of the opinion that they can do so are brought forward one a purely analytical method, the other proceeding from a consideration of the curves of current and E.M.F. If these two lines of argument rested on independent foundations, then their mutual agreement that alternators can so run would give weight. But, unfortunately, both proofs assume that the machines give smooth E.M.F. waves of the sine form and that the armatures have no iron, or, at any rate, that their self-inductions are constant. Further, the serious difficulty arising from "hunting" of the machines is not referred to. Hence the general conclusion, "You may therefore with confidence attempt to run alternate-current machines in parallel circuit for the purpose of producing any external effect," must be regarded as at any rate a bold one.

As a matter of fact, the two machines he experimented on did run in parallel perfectly, and others have since been built to do the same, but it does not follow, and indeed it is not the fact, that all machines possess this property. Dr. Hopkinson, of course, realised the limitations of his equations; indeed, he expressly mentions some of them. Hence in making his prediction we must conclude that he was more influenced by his experimental results than by his theoretical reasoning. In the numerator of the expression which occurs at the bottom of p. 149 of this paper

$$\left.\overline{\frac{2\pi^2}{T}}\right| \text{ should be } \left.\frac{2\pi}{T}\right|^2.$$

A similar criticism as regards limitation in the reasoning may be passed on the equations used at the commencement of paper No. 10, p. 156, vol. i., on "Alternate Current Dynamo Electric Machines." Here he starts with the equation:—

$$Rx = E - (Lx)^{\cdot},$$

where the dot (left out by a printer's mistake on p. 163) signifies differentiation with respect to time. But, as Dr. Hopkinson remarks, "we do not know how L may vary," and so to obtain a solution he assumes L to be independent of time, which of course is not the fact, and so, as he points out, the ordinary theory does not fully account for the facts. This criticism, however, does not apply to the remainder of this paper, which is occupied with an experimental investigation of the currents induced in the coils and in the cores of the magnets of alternate current machines by the varying currents and by the varying position of the armature. A method of determining the efficiency of alternate current machines is also given, and the result used to show that in certain cases of relation of phase of current to phase of electromotive force, the effect of the local currents in the iron cores is to increase instead of to diminish the electromotive force of the machine.

We next come to a short but important paper in which the equations which hold in a transformer with a closed magnetic circuit are given and partially discussed; and in the next paper a method of testing transformers is described and illustrated, the method being similar to that previously given for continuous current dynamos

The remaining papers in this volume, consisting mostly of addresses, do not call for special remark, except for one paragraph, on p. 249, viz., "We know nothing of what light is; we do know that it is a wave." "Is it not infinitely probable that the waves of light are none other than the electrical waves which we know must exist, and must be propagated with the observed velocity of light? And, mark, this theory demands no ether." "Whether the postulate of an all-pervading ether be, or be not, a metaphysical necessity, surely it is well for the practical man and the physicist to leave the question to the metaphysician." Here, then, waves are allowed but an ether is denied, or looked on with suspicion, and so we have apparently to imagine a wave as independent of and apart from any medium; a vibration with nothing to vibrate seems a rather difficult conception. Nor is it easy to see what the metaphysician, in the proper sense of this much abused word, has got to do with the question of an ether; the physicist in his laboratory rather than the metaphysician in his armchair would seem to be the proper man to deal with it.

The papers in the second volume may be roughly divided into three groups. The first group contains papers dealing with residual charge and specific inductive capacity, the second group papers on the magnetisation of iron and the effect of temperature, whilst the third consists of papers on miscellaneous subjects.

The accurate determination of a physical constant of any substance is always a matter of scientific interest, but great additional interest and importance were attached to Dr. Hopkinson's experiments on specific inductive capacity from the fact that, according to Maxwell, the specific inductive capacity of a dielectric ought to be equal to the square of its index of refraction. To appreciate properly the full importance of these experiments we must remember that when Maxwell's treatise appeared in 1873, Maxwell was able to write that there was only one substance, paraffin, the capacity of which was known with sufficient accuracy for a comparison. To this solitary example Dr. Hopkinson added some four different kinds of glass and nine different oils, and it is hardly too much to say that if in all these substances the above relation had been fulfilled, then Hopkinson, and not Hertz, might have been regarded as the man who first experimentally verified Maxwell's theories, although Hertz's work would still have had its great value in connection with the actual propagation of electric waves in space. Unfortunately for Hopkinson, though the relation was found to be true in the hydrocarbon oils, in the vegetable and animal oils and in the glasses it was far from being satisfied.

So far, however, from jumping to the conclusion that Maxwell was wrong, Dr. Hopkinson, in a paper written in 1878, regards it as sufficient to add the caution, "it should not be inferred that his [Maxwell] theory in its more general character is disproved," whilst in a paper written in 1881 he remarks, "It must, however, never be forgotten that the time of disturbance in the actual optical experiment is many thousands of millions of times as short as in the fastest electrical experiment even when the condenser is charged or discharged for only the 1/20,000 second."

Further, in a paper published in 1882, he suggests that a further reason for the discrepancy as regards glass may be the fact that his experiments seem to show that glass would exhibit anomalous dispersion if the spectrum could be examined below the visible rays. Yet another reason for the discrepancy also suggested itself to Dr. Hopkinson, and this was the effect of residual charge, for he regarded capacity, residual charge, and dielectric conductivity, all as ordinarily known, as parts of one continuous phenomenon, and he assumes that we may add the effects of simultaneously, or successively, applied electromotive forces, and that residual charge is proportional to the electric forces producing it. He thus gets the expression:—

$$y_t = \int_0^\infty x\psi(\omega)d\omega,$$

where y_t is the displacement at a time t, x the P.D. applied at a time ω before t, and $\psi(\omega)$ is a function of ω only.

The experimental verification of this formula, and the detailed examination of various substances such as glass, ice, and castor oil, from this point of view are described in two exceedingly interesting papers. The influence of temperature on the phenomena is also examined. It appears from these experiments that the value of the specific inductive capacity of a substance depends on the time of contact. Thus Dr. Hopkinson found that the specific inductive capacity of ice when measured for periods of 1/100th to 1/10th second increases both with rise of temperature and with increase of time, and its value is of the order 80, but when measured for periods such as $1/10^6$ second its value is about 3, and he adds, "We conclude that the great deviation of ice from Maxwell's law is due to residual charge, which comes out between frequencies 10,000 and 100."

We may mention here that there are some misprints in the papers just referred to. On p. 15 equation (6) $\{X\psi(t) - B\}$ should be $X\{\psi(t) - B\}$; on p. 107, in equation (8), V^2/x should be V/x; on p. 113, a slight extension of the upper radius of the lower right-hand quadrant makes it appear as if this quadrant were joined to the right-hand top quadrant; and on p. 120, $dy_t/dt = \psi t$ should be $dy_t/dt = X\psi(t)$, and the reasoning that is given relatively to $\psi(t)$ really applies to $X\psi(t)$.

The magnetic papers commence with one on the magnetisation of iron, its value being greatly enhanced by the chemical analyses which are given of the specimens experimented on. An exact definition of coercive force is given, and the ascending and descending curves are found for a large number of samples by the split bar and yoke method. Attention is also directed to the way in which a small quantity of manganese changes the magnetic properties of iron; thus iron with 12 per cent. of manganese is practically non-magnetic.

The papers dealing with the effects of temperature on the magnetic properties of iron contain some very striking results. It had long been known that iron or steel became non-magnetic when raised to a sufficiently high temperature, viz. about 780° C. This Dr. Hopkinson calls the critical temperature, and he shows that for small magnetising forces the magnetisation of iron increases with rise of temperature until it approaches the critical temperature, but, on further heating, the magnetisation very suddenly almost entirely disappears. It is also shown that as conjectured by Barrett, recalescence occurs at the critical temperature, and that the quantity of heat liberated in recalescence is comparable with the heat required to melt bodies; and, as a further proof of the connection between recalescence and the disappearance of magnetism, Dr. Hopkinson shows that no liberation of heat takes place in a non-magnetisable manganese steel when experimented on in the same way as hard steel and iron.

Most remarkable results were found with certain alloys of iron and nickel. Thus it was found that a specimen containing 25 per cent. of nickel could exist in two different and quite stable states through a range of temperature from a little below freezing to 580° C., one state being non-magnetisable, the other magnetisable. Other physical properties of this alloy were found to change with its magnetic properties; thus its mechanical strength, its extensibility, its electric resistance, its density, are all different in the two states. From the memoir attached to the first volume we learn that Dr. Hopkinson tried if other substances, such as chromium and manganese steel, would behave in a similar manner when experimented on in the same way as the nickel and iron alloy, but none of them showed any sign of becoming magnetic, although cooled in solid carbonic acid.

Next follow papers on magnetic viscosity and on the propagation of magnetisation of iron as effected by the electric currents in the iron. It will be remembered with what interest the experiments on the latter subject were witnessed, and how, when the current was sent round the coil magnetising the block of iron, the ballistic galvanometers attached to the various search coils embedded in the mass deflected with considerable intervals one after the other as the magnetisation reached their respective search coils.

Lastly come papers on the rupture of iron wire by a blow, on the mathematical theory of Tartini's beats, on the effect of internal friction on resonance, on the optical properties of a titano-silicic glass, on the quasi-rigidity of a rapidly moving chain, on the torsional strain which remains on a twisted glass fibre after release from twisting stress, on the stresses caused in an elastic solid by inequalities of temperature, and various others.

At the present time, when so much attention is being given to the development of applied education in this country, it is instructive to look back on this ideal technical teacher, this translator of abstract mathematics into concrete industrial achievements, a man who was so able that he was quite simple and modest—for only mediocrity requires "side"—who sometimes spoke of things as having happened to be carried out by himself, as if it were a matter of mere chance that they had not been originated and accomplished by anyone else. What irony of fate when so many holiday-making Alpine tourists, whose only possible claim to notice consists in their having made some ascent a little earlier in the season or gone a little higher than someone else, return scatheless year after year, that the man who was doing, and had done, great work in the realms of engineering practice and of pure science should have been lost to the world in his prime.

Vol. i is prefaced by a memoir written by his son—the present fitting holder of the chair of engineering at Cambridge—and this memoir, which even filial love and reverence have not made too flattering, forms the best review of the life's work of Dr. Hopkinson.

W. E. AYRTON.

REMINISCENCES.

Notes from a Diary. By Sir M. E. Grant Duff. Vol. i., pp. 317; vol. ii., pp. 326. (London: John Murray, 1904.) Price 18*s*.

SIR MOUNTSTUART GRANT DUFF tells us in his preface that in these two, as in the previous, volumes of his diary he has "resolutely kept to the less serious side of life." They contain no thrilling adventures, no sensational revelations, no acrimonious attacks, no profound metaphysical discussions. They give, however, an interesting picture of the life of a distinguished and cultivated man, with side glimpses of many of the most eminent of our contemporaries both in this and other countries.

For this Sir Mountstuart has had unique opportunities. When he was going to his Governorship of Madras his friends gave him a farewell dinner. It was a gathering of which any man might be proud, and in returning thanks for the toast of the evening, he said with no less truth than good feeling that, when he was young, his ambition had been to make friends of the best and highest of his contemporaries, and that, looking round him, he felt that in this object he had succeeded beyond his most sanguine hopes.

It is probable that many of those who read the diary will fancy that some pieces might have been omitted. I remember at one of our modest X club meetings we all thought that the dinner might be shortened, so as to give us more time for talk afterwards. But when we came to details we could not agree. One suggested to omit the soup, another the fish, a third the joint, and a fourth the pudding. Finally we remained as we were: so I fancy from the present volumes one would omit the botany, another the personal details, a third the theological hints, and so on. But if anyone is disposed to regard some of the details as hardly worthy of record, let him remember how interesting it would be now if Mecænas had left us similar details of his everyday life! What a light it would throw on Roman society and Roman history!

He gives us glimpses, moreover, which show the "art of conversation" at its best. He does not condescend to scandal, or attract attention by ill-natured remarks, or while away time by remarks on the weather. As Mr. Norton says in a typical case, "Flaubert's correspondence, a new edition of Æschylus, the Chanson de Roland, the management of the London Library, Bayreuth, the Euryanthe of Weber, were only a few of the many subjects which came up during our conversation."

The book is admirably adapted for a railway journey, a holiday, or a sick room. It is full of bright sayings, of good stories, of interesting reminiscences of interesting people. It carries us from one country to another, from one society to another: from London to Switzerland and Greece, from politics to theology, from The Club to the Athenæum or the Literary Society.

Sir Mountstuart thinks, and I should not be disposed to differ, that the late Lord Derby was the wisest statesman of his generation. At any rate, probably it would be safe to say that of those who took a leading part, probably none made fewer mistakes.

The botanical notes are numerous. He mentions, for instance, on the authority of Lord Plunket, that Westminster Hall is roofed with oak from the forest of Shillelagh.

The references to zoology are less frequent.

On p. 193 he tells us that Prof. (afterwards Sir William) Flower "gave a very interesting account of the shell of a tortoise which stands in one of the passages. Its original owner was a pet of Laud's, and lived in his garden at Fulham. When he became Archbishop he took the creature to Lambeth, where it lived from 1633 to 1753, when it came by its death, thanks to the folly of a gardener, who dug it up in the middle of winter."

He quotes Aubrey de Vere's happy saying that many people mistake downrightness for uprightness, and again that some people seem to "think they serve God but by serving their neighbour right."

Among other amusing bits are Sydney Smith's dream, "I had a very pleasant dream! I dreamt that there would be in future thirty-nine Muses and only nine articles"; the description of the French coinage of 1848 by a Royalist: "Liberté—point. Egalité—point. Fraternité—point"; which was thus varied: "Liberté de faire du mal. Egalité de misère. Fraternité de Cain et Abel"; the story of an Englishman who "was being driven by a carman through some town, when he saw in front of the Post-Office what he supposed to be the Nine Muses. 'What are those?' he asked his driver. 'The twelve Apostles,' was the answer. 'The twelve Apostles!' he rejoined; 'I can only see nine.' 'Oh,' said the man, 'the other three are inside sorting the Epistles:'"

Bradlaugh's saying with reference to the old and new trades unionism: "The motto of the old Trade Unionists was 'We will!' The motto of the new Trade Unionists is 'You shall!'"

One of the most beautiful of epitaphs, that written by Wordsworth (Bishop of St. Andrews) on his wife:

I nimium dilecta: vocat Deus; I bona nostrae
Pars animae; moerens altera disce sequi.

The names of Gladstone, Disraeli, Salisbury, Lowe, Coleridge, Newman, Stanley, Tennyson, Browning, Dufferin, Matthew Arnold, Huxley, and Flower are among those which flit through the pages. Sir Mountstuart says that he has dealt only with the less serious side of life. In saying so he meant, no doubt, that he does not deal argumentatively with politics, science or theology. The diary brings out, however, clearly his